North American Höganäs

POWDER NEWS

SPECIAL ISSUE
PM²TEC2004
JUNE 13-17, CHICAGO

New Starmix plant for North America

Starmix™ production in the USA starts up in the autumn.

North American Höganäs, Inc. is to produce Starmix™ at a new plant on the Stony Creek site in Pennsylvania.

Starmix™ is a bonded mix, a metal powder concept pioneered and patented by Höganäs AB in the 1980s. Bonded mixes have become an increasingly popular alternative to premixes for gear production and other high-performance applications.

“We are now in the construction phase of the plant and on schedule for an autumn production start,” says Hans Söderhjelm, Vice President of Sales and Marketing for North American Höganäs, Inc. “This is a very important step in improving our service to US customers, as we can offer customized bonded mixes with direct delivery and shorter lead times.”

The new Starmix™ plant significantly extends the product range of North American Höganäs, Inc. which has produced atomized iron and steel powders at the state-of-the-art Stony Creek facility since 2001.

Ralf Carlström, Marketing Manager for P/M at Höganäs AB adds, “End users are driving a trend towards tighter tolerances as they want to make smaller, lighter components. Producing Starmix™ in the USA is another advance in our efforts to provide materials that can cost-effectively match today’s tolerance demands. This new plant will use the best technology available to produce the latest variant of Starmix™, which has been developed over a long period to deliver considerable improvements in filling performance as well as reduced dusting.”

You can find out more about the potential of Starmix™ at the North American Höganäs, Inc. stand at PM²TEC2004 held in Chicago between June 13-17.

Future-oriented presentations

The benefits of Starmix™ will feature in one of 10 technical presentations, plus three special programs, that will be given by the Höganäs Group at PM²TEC2004.

Technology Director of the Tech Center at Stony Creek, Ulf Engström, who worked on development of the original patented Starmix™, says, “We will be giving a wide range of future-oriented presentations on materials and technology that are being adapted to the needs of tomorrow in terms of performance, tolerances and total cost. These areas include bonded mixes, diffusion-bonded materials, soft magnetic composites and P/M solutions for high-performance gears. This year we expect an increased interest in our presentations on chromium materials due to the rocketing prices of conventional alloying elements such as nickel and molybdenum.”

Starmix offers

AN OPTIMUM BLEND OF BENEFITS

Production of Starmix™ at Stony Creek will bring all the advantages of this bonded mix within close reach for US customers.

A number of Höganäs AB presentations have previously highlighted the benefits of the Starmix™ system over unbonded premixes in areas such as fillability, weight variation, dusting and increased productivity during compaction.

Ulf Engström, who was involved in developing the first Starmix™ for Höganäs AB in the early 1980s says, “Some of the advantages of bonded mixes, such as better filling and reduced segregation are well known, but the fact is that Starmix™ also offers the dimensional stability to deliver better final tolerances compared to a part made with a conventional premix.”

This benefit is explored in a presentation at PM^{2}TEC2004: Improvements in Dimensional Consistency Using Starmix™ Bonded Products by Sigurd Berg, Höganäs AB and Daniel Edman, Paul Hofecker, Denis O’Keefe and Ulf Engström of North American Höganäs, Inc.

Good filling performance and minimal segregation are essential if P/M technology is to meet the demands for close dimensional tolerances in precision parts. Starmix™ products are designed to address these issues by bonding ingredients to reduce segregation and increase filling performance.

“This paper looks at the combined effect of the Starmix™ concept and diffusion bonded copper powders on filling performance and dimensional tolerances,” explains Daniel Edman. “While diffusion bonding is restricted to bonding fine metal alloys, Starmix™ is designed for the bonding of organics and

graphite, and the virtually complete bonding of graphite is a prerequisite for optimal tolerances.”

Dimensional scatter tests were carried out on a small 28-tooth gear, which was compacted to a green density of 7.0 g/cm^3 and sintered in a production furnace for 20 minutes in 90% N_2/ 10% H_2 at 2050°F (1120°C).

A die filling simulation involving a non-bonded mix and a Starmix™ showed how well a powder mix fills a die at different filling speeds (see diagram). A low filling index means even filling, delivering a low green density scatter within the part and thus closer tolerances. Daniel comments, “From this simulation, it is obvious that the bonded mix performs better than the non-bonded, especially at higher filling rates.”

The paper’s general conclusion, says Daniel, is that: “Combining a diffusion-bonded copper grade and the superior bonding of graphite using the Starmix™ process, creates a mix with no or very limited segregation of alloying elements. This, in combination with the excellent filling behaviour of a Starmix™ will optimise tolerances for the iron-copper-carbon system.”

Stateside Starmix

The advantages of the latest enhanced Starmix™ version will soon be more readily available to customers in North America.

”There have been big improvements in the Starmix™ product over the past few years in key areas such as filling characteristics, dusting and lubrication,” says Ulf Engström.

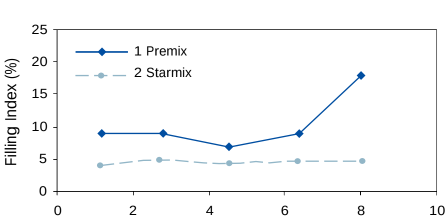
Daniel Edman, who is currently working at Stony Creek in the run up to opening the new Starmix™ plant concludes, “As a part of our continuous development process focused on Starmix™, we have improved both the product and the process in order to better meet customer demands. Now we have greater possibilities to tailor mixes for customers’ applications.”

Focus on bonded mixes

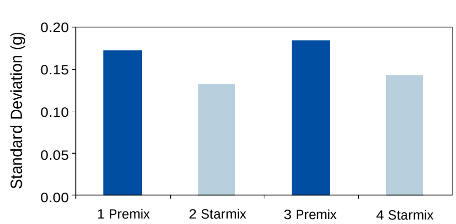
Höganäs AB pioneered and patented the original Starmix™ concept.

The first organically bonded mix carrying the Starmix™ name was launched in the mid-1980s. Critical properties for bonded mixes have been continuously enhanced over the years. Today, bonded mixes are increasingly replacing premixes in gear production and other applications as they offer opportunities to improve efficiency and productivity as well as obtain tighter tolerances.

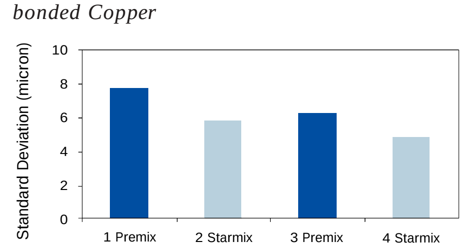
A low Filling Index concludes even density levels between narrow and wider cavities



Green weight scatter at 16 strokes/minute



Sintered diameter scatter of Starmix™ and Premix, with and without the use of diffusion bonded Copper



P/M GEARS EN ROUTE FOR high performance

Höganäs AB has been cooperating with Scania, a leading manufacturer of heavy trucks, to test the potential of various P/M manufacturing routes for high-performance gears.

Warm compaction and surface densification are two performance-enhancing processes that are helping to push P/M technology towards the high strength and fatigue properties required for transmission gears.

The latest research in this area will be presented at PM²TEC2004. High-performance Gears, by Sven Bengtsson and Linnéa Fordén of Höganäs AB and Magnus Bergström of Scania, compares the performance of gears produced by three different manufacturing routes – cold compaction, warm compaction and surface densification

Tests were carried out on a 20-tooth, 700-gramme planetary gear used in the hub reduction unit of Scania heavy trucks. D.AB and Astaloy 85Mo were used as base materials for the P/M prototype gears, which were tested at the Scania Technical Centre in Södertälje, Sweden.

"The interesting thing from a P/M point of view is that these tests were on a gear for a heavy truck," says Sven Bengtsson. "This gear is a critical, heavy-duty component subject to heavy stresses, and it shows how far our technology has come that a P/M solution is being tested for such a high-performance application."

Closing the gap

Gears for this type of application are normally manufactured by forging a blank, followed by turning, hobbing, shaving, heat-treatment and finally grinding.

"These are large gears, which means a lot of material is machined away before the component is finished," states Sven. "Material utilization for solid steel is about 50%, while for P/M it approaches 100%. This means that using a net shape process can achieve a cost saving of 30% compared to a solid steel gear. And now P/M is closing the performance gap, especially when using warm compaction and additional process steps such as surface densification."

Warm compaction, a technique that has been continuously developed since the 1990s, improves density and ensures excellent pore size distribution. Surface densification enhances the fatigue properties of P/M gears, as the density of highly loaded regions can be significantly increased.

Linnéa Fordén says the tests with Scania confirmed the performance-enhancing qualities of warm compaction and surface densification. "With the surface densification route, we achieved a virtually pore-free surface layer along the gear tooth and a surface hardness that was much better than the non-densified materials. It could also be seen that, in comparison with cold compaction, warm compaction elevates tooth root fatigue performance by increasing the density from 7.01 g/cm^3 to 7.44 g/cm^3."

Scania, the world's third-largest producer of heavy trucks, develops and manufactures vehicles with a gross weight of more than 16 tons. "We have cooperated with Scania for many years on various projects such as warm compaction for synchroniser rings," says Sven. "The company is very open to new ideas and active in the hunt for new and better materials and processes. Our cooperation with Scania is slightly unusual as they are an end user rather than a component maker. Cooperation with end users gives us a very good insight on their component performance requirements, and helps us to adapt powders and processes to meet those needs."

Focus on high-performance gears

Höganäs AB is committed to widening applications for P/M gears. Transmission gears for automotive applications is a prioritized R&D area. Extensive resources are being directed to examine both the materials and manufacturing routes that have the potential to reach the required properties. Höganäs AB became involved in surface densification in the early 1980s and the technique been intensively developed since the mid-90s.

High performance made easy

Diffusion-bonded materials offer a robust solution for high-performance components. Two of the best performing diffusion-bonded grades are soon to become MPIF standardized materials.

The robustness of diffusion-bonded materials is a key factor in the quest for high-performance components at low total cost according to Ulf Engström of North American Höganäs, Inc: ”Diffusion-bonded materials offer means to deliver high strength, high precision tolerances in combination with a robustness during manufacturing. This robustness, and the fact that high performance is often gained from a single operation, makes it possible to achieve the right performance levels at the lowest total cost.”

Diffusion bonded grades, a well-established group of materials from Höganäs AB, have enjoyed great success over the past 30 years in markets around the world. Two of the most recent additions, D.DC and D.HP, were introduced in the mid-1990s and are among the fastest growing products in the range.

These two products are examined in the technical presentation, Performance Characteristics of High Performance Diffusion Bonded Materials, by Ulf Engström and Mary Schmidt North American Höganäs, Inc. and Sigurd Berg, Höganäs AB.

The paper describes the performance available from systems using 2% Ni (D.DC) and 4% Ni + 2% Cu (D.HP) diffusion bonded to a 1.5% Mo pre-alloyed base and compares the properties achieved by conventional compaction, conventional and high-temperature sintering and sinterhardening.

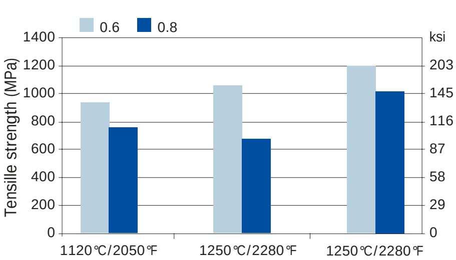
D.DC (Dimensional Control) is a material that offers an important benefit for many applications as the dimensional change remains the same, irrespective of density. D.HP (High Performance) provides very high tensile and fatigue strength that are increasingly in demand for enhancing component performance. This product has proved to be one of the best fatigue materials supplied by Höganäs AB.

Standardized grades

D.HP and D. DC, will shortly complete the testing and approval process to become Metal Powder Industries Federation standardized P/M materials.

“D.DC is due for approval very soon and HP should be approved in the early autumn,” says Ulf. “I think this will be an important step for diffusion-bonded grades in the North American market as once they are in the MPIF standards system, it makes it easier for manufacturers to find out about the products.”

Tensile strength of D.HP-1 for carbon content of 0.6 and 0.8% after sintering at 1120 and 1250°C (before and after tempering operation)



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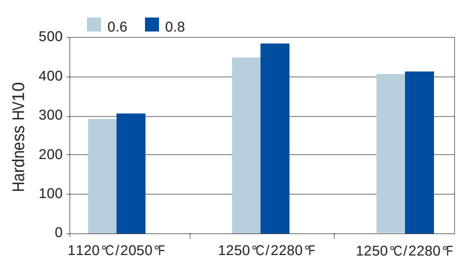


Focus on diffusion-bonded materials

Höganäs AB introduced diffusion-bonded powders between the 1970s and 1990s, and the products has been marketed globally over the years with great success. Ten different grades, offering a range of distinctive properties, are made in Höganäs, Sweden.

In general, the family is characterized by high strength, in particular high fatigue strength. Diffusion-bonded materials are also a very robust product group delivering good characteristics even in less than perfect processing conditions.

PRICE GAP GIVES CHROMIUM AN EDGE

The growing price difference between commonly used P/M alloying elements and chromium is driving a surge of interest in Cr-prealloyed materials.

"With the recent sharp rise in the price of copper, nickel and molybdenum, the low-cost of chromium as an alloying element is becoming even more evident. There is a large body of research which clearly shows that chromium can deliver good properties and good tolerances at a lower total cost, and today's price levels makes it an even more attractive solution," says Ulf Engström of North American Höganäs, Inc.

PM²TEC2004 provides an excellent opportunity to get more acquainted with the benefits of this low-cost, high-strength, environmentally friendly alloying element used in the Cr-Mo prealloyed water-atomized powders, Astaloy CrM™ and Astaloy CrL™.

The Höganäs Group will be presenting two papers on chromium materials. "I think it's a good combination, which will satisfy interest both in what can be achieved today with these materials and what may be possible in the future," comments Ulf.

Properties of High Density Cr-Mo Prealloyed Materials High Temperature Sintered by Bo Hu, Alex Klekovkin, Dave Milligan, Ulf Engström, North American Höganäs, Inc and Sigurd Berg, Barbara Maroli, Höganäs AB, summarizes findings to date on the properties of Cr-Mo prealloyed materials achieved using various compacting techniques, conventional/high temperature sintering and sinterhardening.

Key conclusions

Among the conclusions that can be drawn from existing research are that Cr-Mo prealloyed materials:

- have advantages in achievable properties, sinter hardening response and dimensional control compared to conventional materials such as Fe-Cu and Ni-Mo-Cu alloyed steels
- can be successfully sintered in a conventional N_2-based atmosphere
- provide flexibility for material selection to produce medium to high-strength structural parts
- can achieve desired material properties with less alloying content and better dimensional control compared to conventional Fe-Cu and Ni-Mo-Cu alloyed steels (see Figure 1)
- can maximize their material properties and performance by a combination of high density, high temperature sintering and sinterhardening. With modified processing conditions, a tensile strength of 1200 MPa (174 ksi) for Astaloy CrL™ and 1400 MPa (203 ksi) for Astaloy CrM™ can be achieved at a density of 7.3 g/cm³ (see Figure 2).

Another paper, Process Routes Influence on Performance for PM-Steels Pre-Alloyed with Chromium by Sigurd Berg and Barbara Maroli, Höganäs AB, examines the influence of process conditions on the static and dynamic properties of materials prealloyed with chromium, (see Figures 3 and 4)

Presentation highlights

- Astaloy CrM™ can achieve an excellent combination of strength and toughness after high temperature sintering.
- High temperature sintering followed by cooling at 0.8°C/s results in yield strength of 1100 MPa (160 ksi) and elongation of 1.5% at 7.17 g/cm³ and carbon content 0.5%. If the cooling rate is increased to 2.5°C/s, the yield strength can be increased to 1250 MPa (182 ksi) in combination with an elongation of 1%.
- Fatigue strength is raised from 296 (43 ksi) to 445 MPa (65 ksi) if carbon content is raised from 0.4 to 0.7% – this is at a density of 7.17 g/cm³ and cooling rate of 0.8°C/s. A further increase in fatigue strength can be achieved by shot peening the samples. At 0.7% carbon, the fatigue strength is raised from 445 (65 ksi) to 500 MPa (73 ksi).

Focus on chromium

Höganäs AB has long been a leader in metal powder product development. Chromium, a high-strength, environmentally friendly low-cost alloying element has been the subject of intensive R&D by the company since 1993. In the past 10 years, the Höganäs Group has built up unrivalled knowledge on chromium as a P/M alloying element and introduced the first metal powders pre-alloyed with chromium for mass production applications – Astaloy CrM™ (1998) and Astaloy CrL™ (2002).

Figure 1. Comparisons between Cr-Mo prealloyed materials and conventional P/M materials

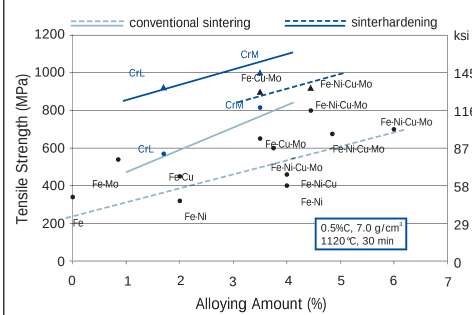


Figure 2. Properties of high density Cr-Mo prealloyed materials enhanced by different sintering processes
(CS: conventional sintering at 1120°C;
SH: sinterhardening at 1120°C;
HTS: high temperature sintering at 1250°C;
HTS+HS: high temperature sintering and sinterhardening at 1250°C)

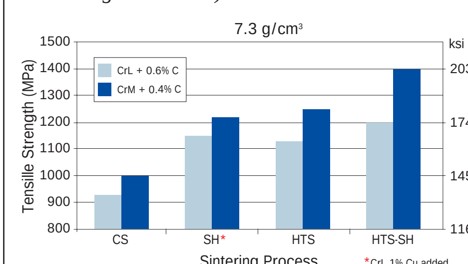


Figure 3. Yield strength vs. carbon content for high temperature sintered samples after cooling at 0.8 and 2.5°C/s

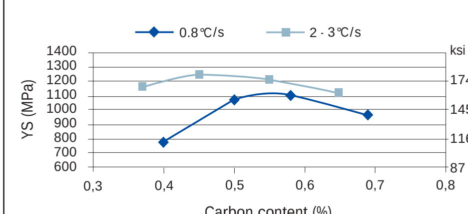
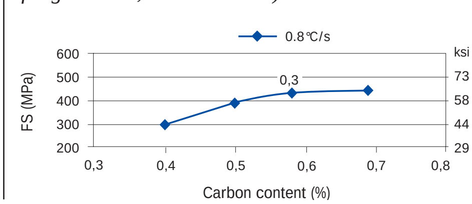


Figure 4. High temperature sintered samples cooled at 0.8°C/s. Plane bending fatigue vs carbon content (Four points plane bending fatigue R=-1, 50% survival)



A springboard

FOR INNOVATIVE MOTOR DESIGN

SMC technology is the ideal platform for new or improved electric motor designs. A presentation on the SMC concept at PM²TEC 2004 explains why.

With a large number of SMC-based electric motors and machines in production around the world, Soft Magnetic Composite (SMC) technology is now an established source of commercial solutions. Two of the latest products to contain SMC components, an electric bike and a linear motor for portable freezers, feature in a presentation at PM²TEC2004, Soft Magnetic Composites – Motor Design Issues and Applications by Lars Hultman of Höganäs AB and Alan Jack of the University of Newcastle upon Tyne.

This general introduction to the SMC concept also presents the technology as a key to innovation. "There is a huge potential market for electric motors and we want to highlight the unique aspects of SMC technology that make new motor designs viable," says Lars Hultman.

"SMC materials are basically pure iron powder particles coated with a very thin electrically insulated layer," explains Lars. "One of the main advantages is 3D-properties; the materials are isotropic and can carry magnetic flux equally well in all directions. Combining these materials with the 3D-shaping capability of the P/M-compaction process has opened up new possibilities in the design and manufacturing of electromagnetic machines and other devices."

Lars points to the wide-ranging potential benefits: "If carefully implemented, the SMC concept can assist in the drive for improved performance, fewer parts, more integrated designs, better product recyclability and a lower total cost."

Prototypes and applications

Two SMC-based prototypes are discussed in the presentation, a compact axial flux machine and a claw pole motor, both constructed by Alan Jack and his department at the University of Newcastle upon Tyne, who have cooperated with Höganäs AB on SMC-related research projects since the mid-1990s.

The paper also shows how SMC technology has been successfully applied in two commercial applications.

Electric bikes produced by the US company, WaveCrest Laboratories, have a direct drive DC motor located in the rear wheel hub. Motor power is up to 750 watts with a peak torque density of 20 Nm/kg (15 lb.ft). These bikes can reach a speed of 32 km/h (20 mph) and have a range of up to 24 km (15 miles). Lars comments: "In this case, SMC technology made it possible to minimize the active mass and core losses of the motor, while maintaining the desired motor performance."

In Japan, Twinbird Corporation has developed a sterling cooler suitable for portable freezers that contains a linear motor with SMC stator parts. "The main advantages of this design compared to laminations are easier assembly and cheaper parts," says Lars.

Lars stresses that results with SMC require more than replacement of laminate components. "To take full advantage of the SMC concept, you need to redesign from today's 2-D steel laminate solutions to new 3D-designs. Höganäs AB helps customers starting out with SMC every step of the way. We offer support in areas such as powder selection, processes, furnace settings, component manufacturing and applications, as well as initial design support to analyze proposed components."

Focus on SMC technology

Höganäs AB launched the first SMC materials in 1993 and has been the leading R&D force in this specialized field ever since. The Group is driving SMC technology forward through technical development of materials and processes for new components. Cooperation with end users is considered an essential element in advancing SMC technology. The Höganäs Group is currently involved in more than 40 projects with manufacturers of electrical machines, primarily motor producers.

WaveCrest Tidal Force bike
(Courtesy of Wavecrest Laboratories, USA)

Twinbird Sterling Cooler
(Courtesy of Twinbird Co Ltd. Japan)

SPONGE IRON POWDERS ARE STILL GOING STRONG

Sponge iron powders still have an important role in today's P/M industry and offer distinct advantages, particularly for component producers looking for fine tolerances in medium-strength applications.

Höganäs AB has manufactured sponge iron powders for almost 100 years and remains the world's largest producer. Initially supplied to Swedish steel makers, the company's sponge iron powders were used in the compacting and sintering developments of the 1930s to establish the basis for today's P/M industry. Other iron powder production methods such as water atomization were developed in the 1950s, but sponge iron powders remain highly relevant to modern needs.

"The success of water-atomized powders should not obscure the fact that sponge iron powders are still popular and offer a range of excellent benefits. These products are well-proven with properties that in certain cases make them a better choice for medium-strength applications than atomized powders," says Mats Larsson of Höganäs AB, who answered our key questions on sponge iron powders.

Does particle shape have an effect?

Sponge iron particles have a spongy internal structure (see figure 1), while water-atomized particles have very little internal porosity. The irregular shape and porous interior of sponge iron powder particles gives it a better green strength after compacting than powders with a regular particle shape. High green strength makes components easier to handle and gives high edge strength.

What is considered a good all-round sponge iron powder?

The benefits of particle shape on high green strength can be clearly seen in NC100.24, one of the most widely used grades in the manufacturing of sintered parts, especially structural parts where high green strength after pressing is an important quality.

Is compressibility an issue?

The porous structure of sponge iron powders means they generally offer lower compressibility than atomized powders. However, there are sponge iron powders with good compressibility. SC100.26 has been optimized to provide the best compressibility of all Höganäs AB sponge iron powders. It combines good compressibility with high green strength (see figure 2), which makes it a good alternative to the atomized AHC100.29.

Do these powders have any special applications?

Yes, high green strength at low densities makes sponge iron powder uniquely suitable for self-lubricating bearings. One of our powders, MH80.23, has been especially designed to match the requirements for this application with a particle size that creates an optimal pore structure.

How pure is sponge iron powder?

All our sponge iron powders for the P/M industry are produced in Höganäs from virgin material rather than scrap metal. Using virgin material means a lower level of metallic impurities and this ensures greater consistency in the powder's chemical composition.

Why are these products relevant to today's needs?

One aspect of sponge iron powders that has become more important to component producers is small dimensional scatter (see figure 3). There is a clear trend towards finer tolerances for components and one of the important factors is having a base material that provides lower scatter. Our experience is that you can achieve lower scatter with sponge iron than certain atomized powders.

When is sponge iron a better powder choice than water-atomized?

For self-lubricating bearings and low-density applications, sponge iron powders are the recognized choice, whereas water-atomized powders are best for high-strength components. In the medium-strength segment, which includes structural parts such as belt pulleys, there is an overlap where you can choose either an atomized or sponge iron powder. In many cases it's better to select a sponge iron powder because the lower dimensional scatter gives you access to the finer tolerances that are required today.

Figure 1. External particle shape and internal particle structure of sponge iron powder (NC100.24) and water atomized iron powder (ASC100.29)

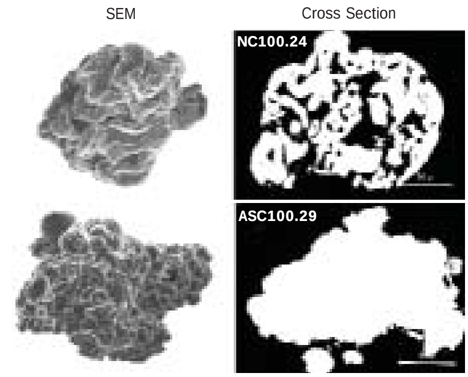
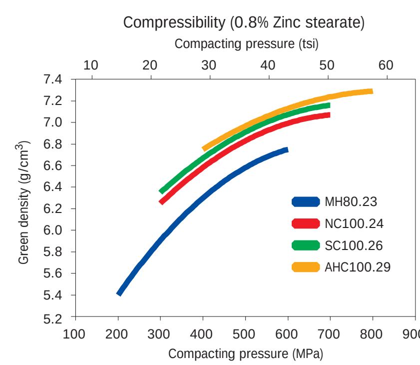


Figure 2. Compressibility and green strength of iron powder grades mixed with 0.8% zinc stearate



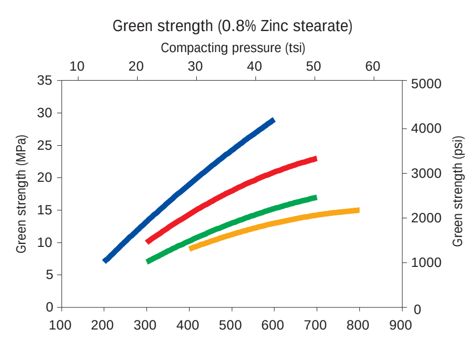
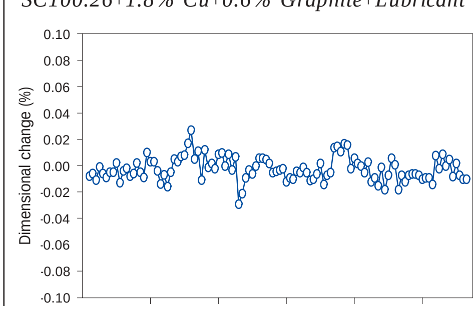


Figure 3. Dimensional change of lots produced over a period of one year of a Starmix containing SC100.26+1.8% Cu+0.6% Graphite+Lubricant



TECHNICAL PRESENTATIONS

AT THE PM²TEC2004 CONFERENCE, CHICAGO, JUNE 14-17

Monday June 14

Performance Characteristics of High Performance Diffusion Bonded Materials

North American Höganäs,Inc.
Mary E. Schmidt
Ulf Engström

Höganäs AB
Sigurd Berg

Effect of Time at Temperature and Cooling Rate on Properties of Sinter Hardenable Materials

North American Höganäs,Inc.
Mary E. Schmidt
Peter J. Thorne
Ulf Engström

Abbott Furnace Company
Stephen Feldbauer
Thomas J.Jesberger
Jason Gabler

Tuesday June 15

Comparison of Methods of Reaching High Green Densities Using Elevated Temperatures

North American Höganäs, Inc.
Paul Hofecker
David Milligan
Ulf Engström

Höganäs AB
Sigurd Berg

Effect of Processing Parameters on the Room and Elevated Temperature Mechanical Properties of P/M 409L and 434L, Stainless Steels

North American Höganäs,Inc.
Prasan K. Samal

Höganäs AB
Owe Mårs
Ricardo C. Leyton

Wednesday June 16

Pre-Alloyed Chromium Materials for Highly Fatigue Loaded PM Parts

Höganäs AB
Anders Bergmark
Ola Bergman
Luigi Alzati

Properties of High Density Cr-Mo Pre-Alloyed Materials High Temperature Sintered

North American Höganäs, Inc.
David Milligan
Alex Klekovkin
Ulf Engström
Bo Hu

Höganäs AB
Sigurd Berg
Barbra Maroli

Process Routes Influence on Performance for PM-Steels Pre-Alloyed with Chromium

Höganäs AB
Sigurd Berg
Barbara Maroli

Improvements In Dimensional Consistency Using Starmix™ Bonded Products

North American Höganäs, Inc.
Daniel Edman
Denis O'Keefe
Ulf Engström
Paul Hofecker

Höganäs AB
Sigurd Berg

SPECIAL INTEREST PROGRAMS

PM Technologies for Growth

North American Höganäs,Inc.
Hans Söderhjelm

Soft Magnetic Composite Materials

Höganäs AB
Lars Hultman

Soft Magnetic Composites in Automotive Applications

Höganäs AB
Lars Hultman

Thursday June 17

Soft Magnetic Composites-Motor Design Issues and Applications

Höganäs AB
Lars O. Hultman

Univeristy of Newcastle Upon Tyne
Alan Jack

High Performance Gears

Höganäs AB
Sven Bengtsson
Linnea Fordén

Scania
Magnus Bergström

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North American Höganäs

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